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The Validity of the Circumduction Test in Elderly Men and Women

***Koen A.P.M. Lemmink, Han C.G. Kemper, Mathieu H.G. de Greef,
Piet Rispens, and Martin Stevens***

This article focuses on the validity of the circumduction test for measuring shoulder flexibility in older adults. Participants included 137 community-dwelling older adults. Equipment consisted of a cord with a fixed handle on one end and a sliding handle on the other. The sliding handle was adjusted so that the cord length between the 2 handles equaled the participant's shoulder width. Holding the 2 handles, the participant must pass the cord from the front of the body over the head and as far back as possible with extended arms. The score is the fanning-out angle. Forward flexion, abduction, horizontal retroflexion, and outward rotation were also measured. The test and criterion measurements were administered within 1 wk. The criterion-related validity of the circumduction test as a measure of forward flexion and horizontal retroflexion received support from moderate correlations. Its use as a measure of abduction and outward rotation, however, received no support from the data.

Key Words: shoulder flexibility, range of motion, field-based assessment, motor fitness

Field-based assessment of fitness has a long tradition, especially in schoolchildren (American Alliance for Health, Physical Education, Recreation and Dance [AAHPERD], 1976, 1984; Council of Europe, 1988; Kemper & van Mechelen, 1996). In adults, fitness testing has become increasingly popular, for example, as a tool for stimulating physical activity in large populations (Fitness and Amateur Sport Canada, 1986; Oja & Tuxworth, 1995; Suni et al., 1996). In recent years, fitness test batteries have also been developed for the elderly (Lemmink, van Heuvelen, Rispens, Brouwer, & Bult, 1995; Osness et al., 1990; Rikli & Jones, 1999).

The Groningen Fitness Test for the Elderly (GFE) was developed for field-based assessment of motor fitness in self-reliant adults over the age of 55 (Lemmink, 1996; Lemmink, Kemper, de Greef, Rispens, & Stevens, 2001; Lemmink et al., 1995). In recent years the GFE has been used to examine the relationship between motor fitness and physical activity, health, and daily functioning in elderly people (Van Heuvelen, Rispens, Lemmink, & Brouwer, 1994; Voorrips, Lemmink, van

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Heuvelen, Bult, & Van Staveren, 1993). It is currently used throughout the Netherlands as part of the GALM (Groningen Active Living Model) strategy to stimulate physical activity in sedentary older adults (Stevens, Bult, de Greef, Lemmink, & Rispen, 1999; Stevens, Lemmink, de Greef, & Rispen, 2000).

Shoulder flexibility is an important component of physical fitness in the elderly (Shephard, Berridge, & Montelpare, 1990; Rikli & Jones, 1999). A lack of flexibility is associated with problems in executing and sustaining motor activities in daily life (Bergström et al., 1985; Johnston & Smidt, 1970; Myers & Huddy, 1985). Adequate shoulder flexibility is required for all kinds of everyday functions such as dressing, combing one's hair, reaching up to a high shelf, or hanging up laundry. Reduced shoulder flexibility is associated with postural instability (Magee, 1992) and disability (Chakravarty & Webley, 1993).

Two test items of the GFE measure aspects of flexibility: The sit-and-reach test measures flexibility of the hamstrings and lower back, and the circumduction test measures shoulder flexibility (Lemmink et al., 1995). This article focuses on the circumduction test. The circumduction test is based on a test described in German literature in which the participant had to pass a wooden stick from the front of the body, over the head, and as far back as possible (circumduction movement). This movement had to be made with extended arms and with the hands as close as possible to one another. The score was the smallest distance between the hands on the wooden stick that could be maintained without bending the arms (Hannig, 1983; Richter & Beuker, 1968). We adapted the test in two ways: First, to minimize risk of injury, a rope was used instead of a wooden stick. Second, a new scoring procedure was developed to take into account differences in arm length among the participants.

Recently, Rikli and Jones described the modified back-scratch test (1999). This protocol involves reaching behind the head with one hand and behind the back with the other, trying to touch the middle fingers of both hands together. That test, which was developed to measure a combination of shoulder flexion and extension, abduction and adduction, and internal and external rotation, involves measuring the distance between (or the overlap of) the middle fingers behind the back. The back-scratch test proved to be reliable (Miotto, Chodzko-Zajko, Reich, & Supler, 1999; Rikli & Jones). It is considered by experts in the field to be a valid assessment of overall shoulder range of motion and discriminates between age groups and between exercisers and nonexercisers (Rikli & Jones).

The reliability of the circumduction test has proven to be satisfactory (Lemmink et al., 2001). Validity research showed that the circumduction test discriminates between sex and age groups (Lemmink, 1996) and between physical activity levels (Voorrips et al., 1993). The purpose of the present study was to examine the criterion-related validity of the circumduction test against criterion measures of shoulder flexibility, that is, forward flexion, abduction, horizontal retroflexion, and outward rotation, in elderly men and women.

Method

PARTICIPANTS

The experimental group consisted of individuals who replied to a direct mailing we had sent to a random stratified sample of independently living adults over the age

of 55 in five municipalities of the northern Netherlands. The sample was stratified by age (55–59, 60–64, 65–69, 70–74, and 75+ years), and names were retrieved from municipal records. In total, the stratified sample included 1,505 men and women, 458 of whom agreed to participate (a response rate of 30.4%). The participants were informed about the study's procedures before giving their verbal participation consent. The procedures complied with the ethical standards of the Medical Faculty of the University of Groningen. The study consisted of two testing sessions in local sports centers. Data for the study were collected as part of a larger study examining the reliability and criterion-related validity of the GFE (Lemmink et al., 2001).

SAFETY PROCEDURES

Safety procedures consisted of a medical screening of all participants by a supervising physician before their participation in the GFE. The medical screening included a brief medical questionnaire, a blood-pressure measurement, and consultation with an attending physician. Thirteen participants out of 458 in total were excluded from the circumduction test because of orthopedic problems (2.8%). The most frequently reported health problems were high blood pressure (33%), tiredness/dizziness (27%), and bone or joint problems (21%).

VALIDITY ASSESSMENT

Participants were invited to participate in two test sessions with a 1-week interval between the sessions. During the first test session (T1), the circumduction test was administered to all participants. After the first session we split the sample into three groups, depending on the time of day of their first session. One subgroup ($n = 137$) was invited for supplementary measurements to determine criterion measures for shoulder flexibility 1 week later. Six participants were already excluded at the first test session because of orthopedic problems (4.4%). Ten participants (7.3%) did not show up at the second test session. In 5 participants (2.9%), the procedures for the determination of the criterion measures could not be properly executed (3.6%). The other two subgroups did the test items of the GFE again to determine reliability; the data of that particular study are reported elsewhere (Lemmink et al., 2001).

Before testing, examiners took a 1-day course on proper execution of the circumduction test and criterion measures. They were all medical or human-movement-science students or graduates. All examiners of the criterion measures were physiotherapists experienced in measuring flexibility. Examiners practiced on each other during the day until they were able to demonstrate procedures in a standard manner, described in the test protocols, to the project coordinators.

CIRCUMDUCTION TEST

The circumduction test is part of the GFE and was developed to measure shoulder flexibility (Lemmink, 1996; Lemmink et al., 2001; Voorrips et al., 1993). First, the length of the arm in centimeters is measured from the acromion to the metacarpal phalanx joint of the middle finger with a tape measure. The equipment consists of a cord with a fixed handle on one end and a sliding handle on the other. The sliding

handle is adjusted so that the length of the cord between the insides of the two handles is equivalent to the participant's shoulder width (from acromion to acromion). Holding the two handles of the cord, the participant must pass the cord from the front of the body over the head and then as far back as possible (Figure 1). This movement must be made with extended arms, and the participant must try to keep his or her arms from fanning out more than is physically necessary to complete the movement. The score is the fanning-out angle, in degrees, calculated with the following formula: $\text{Score} = \text{angle} (^{\circ}) = \arccos S/2L$, where S = the shift of the sliding handle in centimeters during the movement and L = the length of the arm in centimeters from acromion to metacarpal phalanx joint of the middle finger (Figure 2). After a practice trial, the best score out of three trials is recorded. A higher score means a better performance, that is, better shoulder flexibility.



Figure 1. Procedures of the circumduction test.

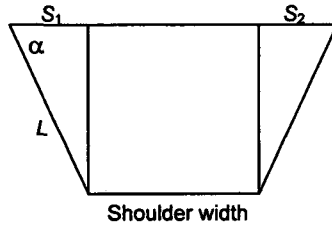


Figure 2. Scoring procedure of the circumduction test. Score = angle α = arc cos $S/2L$; $S = S_1 + S_2$ = shift of sliding handle in centimeters during the movement; L = length of the arm in centimeters from acromion to metacarpal phalanx joint of the middle finger.

GONIOMETRIC MEASUREMENTS

Forward flexion, abduction, horizontal retroflexion, and outward rotation were measured as the range of motion in the shoulder joint and related musculature by a manual goniometer, a standard clinical-assessment device that expresses range of motion in degrees. The measurements were performed with the participant standing erect, following procedures of the American Academy of Orthopaedic Surgeons (1966).

Forward flexion was measured as the forward upward motion of the arm in the anterior sagittal plane of the body, from zero to maximally 180°. Abduction was measured as the upward motion of the arm away from the side of the body in the coronal plane, from zero to maximally 180°. Horizontal retroflexion (horizontal extension) was measured as the horizontal motion posterior to the coronal plane of the body. Outward rotation was measured as the outward rotation to maximally 80° with the arm at the side of the body and the elbow flexed 90°.

Each range-of-motion score was determined as the mean of two measurements of both the left and the right side. Several authors have demonstrated the reliability of measuring joint range of motion (Boone et al., 1978; Ekstrand, Wiktorsson, Öberg, & Gillquist, 1982; Low, 1976).

STATISTICAL METHODS

Standard SPSS statistical packages were used to estimate means and standard deviations of the circumduction-test scores and criterion measures of shoulder flexibility. To determine validity, the data were analyzed with Pearson correlation coefficients (r) and 95% confidence intervals between the circumduction test and goniometric measurements of forward flexion, abduction, horizontal retroflexion, and outward rotation. Because the purpose of the circumduction test is to measure shoulder flexibility, a stepwise multiple-regression analysis was conducted to assess the relationship between the circumduction test and a combination of forward flexion, abduction, horizontal retroflexion, and outward rotation. All analyses were conducted separately for men and women.

Results

Descriptive statistics of the participants are presented in Table 1. Flexibility characteristics indicate superior flexibility in the women for all measurements (Table 2).

Table 1 Age, Height, and Weight of the Participants

	Men (<i>n</i> = 61)		Women (<i>n</i> = 76)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Age (years)	67.8	7.64	65.7	8.47
Height (cm)	174.3	6.26	162.2	6.12
Weight (kg)	81.0	10.00	73.1	11.09

Table 2 Flexibility Characteristics for the Participants, in Degrees

	Men (<i>n</i> = 46)		Women (<i>n</i> = 70)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Circumduction test	41.9	4.69	46.7	6.70
Forward flexion	152.0	13.77	155.9	14.77
Abduction	153.9	19.41	159.3	17.82
Horizontal retroflexion	22.1	6.11	24.3	7.40
Outward rotation	45.6	11.38	49.9	12.24

Table 3 shows the correlation coefficients and 95% confidence intervals between the circumduction test and the criterion measures. Correlation coefficients range from low to moderate in men ($.24 < r < .51$) and women ($.37 < r < .64$). Except for the correlation between forward flexion and abduction (.76 in men and .82 in women), the correlations between the criterion measurements show only low correlations for men ($.08 < r < .45$) and women ($.24 < r < .34$).

The results of the stepwise multiple-regression analyses for the circumduction test, including the standardized beta weights, multiple *R*, *R*², *SE*, and *p* values, are provided in Table 4. The stepwise regression placed horizontal retroflexion as the first significant predictor of the circumduction test for men, with a percentage of shared variance of 26 ($p < .05$). When the other range-of-motion scores were added into the prediction equation, the shared variance increased by only 8%, indicating that little variation was explained after these scores had been included in the multiple prediction. The contribution of these scores to the percentage of shared variance was not significant ($p > .05$). For women, the stepwise regression placed forward flexion as the first predictor of the circumduction test, with a percentage of shared variance of 41 ($p < .05$). When horizontal flexion was added in to the prediction equation, the shared variance increased by 8% ($p < .05$). When outward

Table 3 Correlation Matrix (Pearson Correlation Coefficients and 95% Confidence Intervals) for the Circumduction Test and the Criterion Measures, in Degrees

	Circumduction	Forward flexion	Abduction	Horizontal retroflexion	Outward rotation
Men (<i>n</i> = 46)					
circumduction	—	.44 (.17-.65)	.34 (.06-.57)	.51 (.26-.70)	.24 (-.05-.50)
forward flexion	—	—	.76 (.60-.86)	.45 (.18-.65)	.08 (-.22-.36)
abduction	—	—	—	.42 (.15-.63)	.22 (-.08-.48)
horizontal retroflexion	—	—	—	—	.21 (-.09-.47)
outward rotation	—	—	—	—	—
Women (<i>n</i> = 70)					
circumduction	—	.64 (.48-.76)	.54 (.35-.69)	.49 (.29-.65)	.37 (.15-.56)
forward flexion	—	—	.82 (.72-.88)	.34 (.11-.53)	.24 (.01-.45)
abduction	—	—	—	.30 (.07-.50)	.24 (.01-.45)
horizontal retroflexion	—	—	—	—	.34 (.11-.53)
outward rotation	—	—	—	—	—

Table 4 Multiple-Regression Analysis (Stepwise) for the Circumduction Test and the Criterion Measures, in Degrees

	Beta	R	R ²	SE	p
Men (n = 46)					
horizontal retroflexion	.51	.51	.26	4.09	.000*
forward flexion	.26	—	—	—	.067
abduction	.16	—	—	—	.268
outward rotation	.14	—	—	—	.300
Women (n = 70)					
forward flexion	.64	.64	.41	5.18	.000*
horizontal retroflexion	.30	.70	.49	4.84	.002*
outward rotation	.16	—	—	—	.080
abduction	.01	—	—	—	.948

Note. Beta = standardized beta weights; R = multiple-correlation coefficient; R² = shared variance; SE = standard error of prediction.

* $p < .05$

rotation and abduction were added, the shared variance increased by only 3%, indicating that little variation was explained after outward rotation and abduction had been included in the multiple prediction. The contribution of outward rotation and abduction to the percentage of shared variance was not significant ($p > .05$).

Discussion

The stated purpose of the present study was to determine the relationship between the circumduction test and criterion measures of shoulder flexibility in elderly men and women, because the test is used as a measure of shoulder flexibility. This study focused on criterion-related validity, which is one component of validity. The content validity of the circumduction test is supported through expert opinions and is based on existing test procedures described in literature (Hannig, 1983; Richter & Beuker, 1968). The construct, or discriminant, validity has been supported by demonstration of the sensitivity of the test for sex, age groups, and habitual physical activity levels of elderly women (Lemmink, 1996; Voorrips et al., 1993). More information is needed, however, on whether the circumduction test is sensitive to change as a result of participating in an exercise program. At the time of this writing, a longitudinal study is being carried out in which changes as a result of participation in an exercise program will be determined.

The circumduction test produces reliable scores in elderly men and women from trial to trial at one test session (ICC = .93 for men, .95 for women), from test session to test session (ICC = .88 for men, .84 for women), and from rater to rater

(ICC = .83 for men, .78 for women). Furthermore, 95% confidence intervals of the mean differences between the different measures of the circumduction test illustrated reasonable agreement (Lemmink et al., 2001). The test protocols for the goniometric measurements were taken from the literature, where their reliability and validity had been previously demonstrated (Boone et al., 1978; Gajdosik & Bohannon, 1987; Low, 1976; Stratford, Agostino, Brazeau, & Gowitzke, 1984).

The superior flexibility of elderly women as demonstrated in the circumduction test is consistent with past findings (Lemmink, 1996, Lemmink et al., 2001). In general, the range-of-motion scores in our participants are consistent with previous findings (Miller, 1985). Women's higher measurements in range of motion are also in agreement with data from previous studies (Bell & Hoshizaki, 1981; Clarke, 1975).

Results indicated that the circumduction test was moderately related to forward flexion, abduction, and horizontal retroflexion, but its relation to outward rotation was low. Criterion measures of forward flexion and abduction were strongly interrelated in elderly men and women ($r = .76$ and $.82$), respectively. Baumgartner and Jackson (1995) suggest that a correlation of at least .90 is desirable, but values exceeding .80 are acceptable. In some situations, values of .50 or .60 might be acceptable. The acceptable value of the validity coefficient depends on many aspects such as the type of coefficient, the quality of the criterion measure, and the level of the needed or expected validity coefficient based on what others have obtained in similar situations.

We developed a new field test for measuring shoulder flexibility that was more appropriate for our target group; consequently, there are no earlier data with which to compare our criterion-related-validity results. Rikli and Jones (1999) described the back scratch as a method of measuring shoulder range of motion in the field setting. The test, which involves simply trying to touch the middle fingers of both hands together behind the back, is quantified as the distance between (or the overlap of) the middle fingers. The authors claim that the back-scratch test assesses shoulder flexion and extension, abduction and adduction, and internal and external rotation, and experts consider the test a valid assessment of overall shoulder range of motion. Nonetheless, no data on criterion-related validity are available for this test.

The results of the stepwise multiple-regression analysis indicated that forward flexion and horizontal retroflexion combined contribute significantly to explaining variation in the circumduction test for elderly women, with a percentage of shared variance of 41. In elderly men, only horizontal retroflexion contributed significantly toward explaining variation in the circumduction test, with a shared variance of 26%. As a result of the high correlations between abduction and forward flexion in elderly men and women, abduction does not appear to contribute separately toward explaining variation in the circumduction test. The reasons for the difference between men and women are not quite clear. Future research should examine the inconsistencies between elderly men and women.

Although we believe that we selected the most relevant criterion measures, it should be noted that the range-of-motion measurements of four isolated movements in this study are a simplification of the complex reality of circumduction. For instance, glenohumeral and scapulothoracic motions and range of motion in the wrists might play a role in the circumduction movement in our test. A more

comprehensive determination of movements in the shoulder might shed light on the nature and importance of the different movements in the shoulder in relation to circumduction-test performance.

In conclusion, the criterion-related validity of the circumduction test as a measure of forward flexion and horizontal retroflexion received support from the moderate correlations. This test could therefore be deemed an acceptable measure of forward flexion and horizontal retroflexion and be used in situations in which that is the measurement objective. Its use as a measure of abduction and outward rotation receives no support from the data of this study. If abduction and outward rotation are to be measured in field circumstances, a specific field test should be developed that is easy to administer and not time consuming.

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